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Disk inspection system by two dimensional birefringence distribution measurement

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ABSTRACT

Several kinds of disks, such as DVD, MO and/or CD-R, for the next generation require high quality of plastic surface. Especially their flatness is very important. Here a disk inspection system is proposed using two dimensional birefringence distribution measurement. Small birefringence is a serious problem that is caused by internal strain, and/or residual stress. Moreover it is possible to observe its molecular orientation. The birefringence measurement is necessary to determine the relative retardation and the azimuthal angle of the fast axis in an optical disk. Several images captured by a CCD camera are enough for one birefringence distribution analysis. Experimental procedure and their results of some famous optical disks are discussed.

Keywords: disk inspection, birefringence measurement, phase shifting technique

1. INTRODUCTION

Recently, a birefringence measurement, especially for optical discs, plastic lenses or glass substrates is important for manufacturing inspection process. Many plastic disks, such as several kinds of CDs, DVDs and next generation hard disks, are used for the data storage system. An injection process is used for manufacturing their plastic disks. A flatness is the most important for a disk manufacturing process. Many researchers suggested the main reason for the defects of flatness is residual stress but there are few reports of its experimental results.

In this report, we propose a disk inspection system by two-dimensional (2-D) birefringence measurement. It is necessary for the birefringence measurement to determine both the relative retardation and the azimuthal angle of the fast axis in a sample. Until now, modulation techniques utilizing a photoelastic modulator or an optical heterodyne method[1,2] have been reported and also commercialized on the market. However, since these 2-D birefringence distribution measurements are single point measurement methods, the sample needs to be moved mechanically. These methods are time cosuming and such systems are apt to be large. Nowadays, there are many papers related to two dimensional birefringence distribution measurement. [3-5].

In this paper we propose an improved method and device for measurement of 2-D retardance and principal plane azimuth distributions from intensity of the polarimeter using a phase shifting technique. In our trial both the phase retardation and the principal axis distribution can be determined without moving or rotating the sample. The basic expressions that describe the operation of the systems are presented. A microscopic birefringence measurement is also proposed to analyze an inside of the disk. Finally, we show some experimental results of disks.

2. PRINCIPLE OF DISK INSPECTION SYSTEM

An optical configuration of a disk inspection system by 2-D birefringence measurement is shown in Fig.1. The system based on a polarimeter using a phase shifting method. A liner polarized beam from He-Ne laser at 632.8nm passed through a Babinet-Soleil compensator (BSC) as a retarder and its phase is changed by the birefringence of the sample. An intensity I at a CCD camera after the polarizer can be easily expressed using Stokes parameters and Mueller matrix, as follows [6-8].

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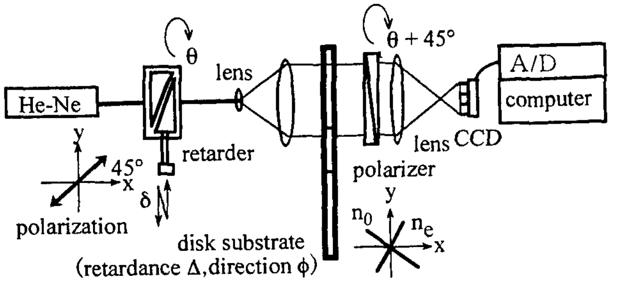


Fig. 1 Principle set up for disk inspection by two dimensional birefringence measurement.

$$I = {}^{1}/_{2} \cdot I_0 \cdot [\, 1 - \cos \{ \tan^{-1} (\Delta \cos (2\theta - 2\phi)) + \delta \} \,] \quad (1)$$

We use twice the phase shifting technique to determine the birefringence parameters Δ and ϕ.

First, the azimuthal angle θ of the BSC is adjusted as 0 deg and a vector Φ can be calculated the intensity I_0~I_3 of the polarimeter to change the retardation of BSC δ as 90deg of each time using the phase shifting technique.

$$\Delta \cdot \cos (2\theta - 2\phi) = \frac{I_1 - I_3}{I_0 - I_2} = \Phi \quad (2)$$

Next, the phase Φ changes sinusoidal as two periods concerning one rotation of the retarder θ. We can easily get the retardance Δ and the azimuthal angle ϕ using 4-step method in case of the rotation angle of θ. As there are two unknown parameters in Eq.(2), six or eight images are enough to analyze birefringence distribution. We analyze birefringence parameters, such as retardance Δ and azimuthal direction ϕ, using 16 images for improving resolution as follows.

$$\phi = \frac{1}{2} \tan^{-1} \frac{\Phi_1 - \Phi_3}{\Phi_0 - \Phi_2} \quad (3).$$

$$\Delta = \frac{1}{2} \sqrt{(\Phi_2 - \Phi_0)^2 + (\Phi_3 - \Phi_1)^2} \quad (4)$$

For this analysis, we have checked both retardance and azimuthal direction errors as ±1deg. Its measurement time is expected less than 1 min. using a liquid crystal retardaer and electrical control stage to rotate a polarizer.

The local-sampling phase shifting technique is more powerful method to improve a resolution of the retardance[9]. Figure 2 shows its result compared with a calibrated phase difference known birefringence distribution, a Babinet-Soleil compensator as a specimen, was examined to check sensitivity and accuracy of this system shown in Fig.(3). At first the principal axis direction of a Babinet-Soleil compensator is set to 0 degrees and the variation of the birefringence phase difference is tested. Figure 3(a) shows the result of the measured birefringence phase difference that is given by changing the thickness of the wedge using a micrometer of Babinet-Soleil compensator. The symbols circles indicate the measured results by this method and the straight-line means the calibration line. We archived a retardance as ±0.02deg.

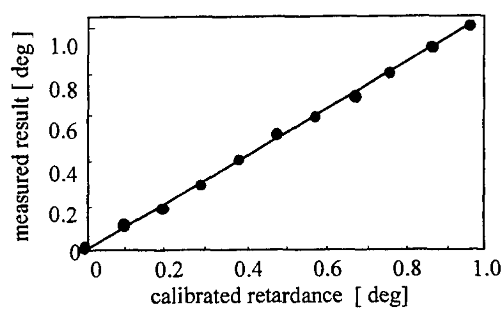
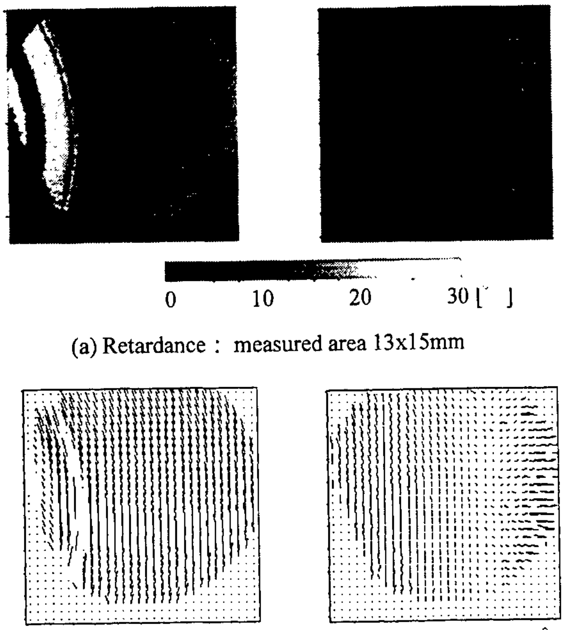


Fig.2 Calibrated result in small birefringence range using a local sampling method

3. EXPERIMENT RESULTS OF OPTICAL DISKS

Figure 3 shows the 2-D birefringence distribution of a DVD-R optical disk both inside and outside. The measurement area is limited to 13x15mm by the optics used in this experimental setup. The retardation is shown in gray scale in the image in Fig.3(a). Fig.3(b) means the vector plot which indicate the azimuthal direction.



(a) Retardance : measured area 13x15mm

(b) Vector plot

Fig.3 Birefringence distribution of DVD-R

Figure 4 is the results of the optical disks, such as CD-R, CD-ROM, DVD-ROM, and DVD-R. There is an interesting result that the retardance is double even if the thickness of the CD is twice comparing the DVD.

Moreover, we built up a microscopic type of a

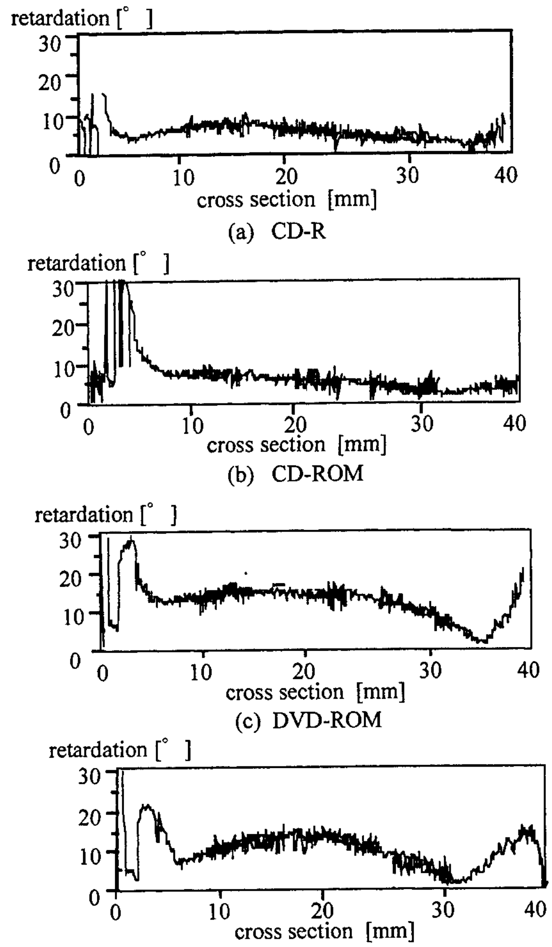


Fig.4 Measured results of optical disks

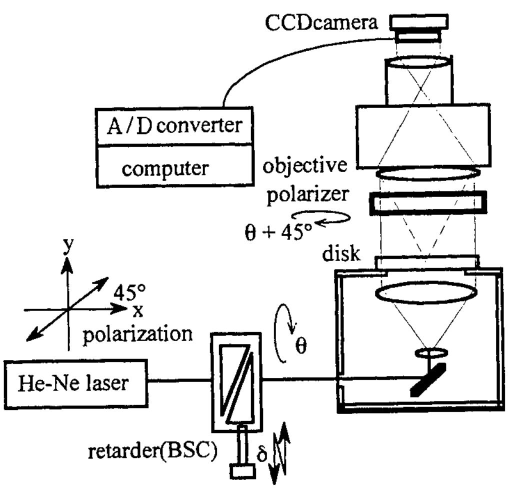


Fig.5 Microscopic measurement system of birefringence distribution inside disk substrate

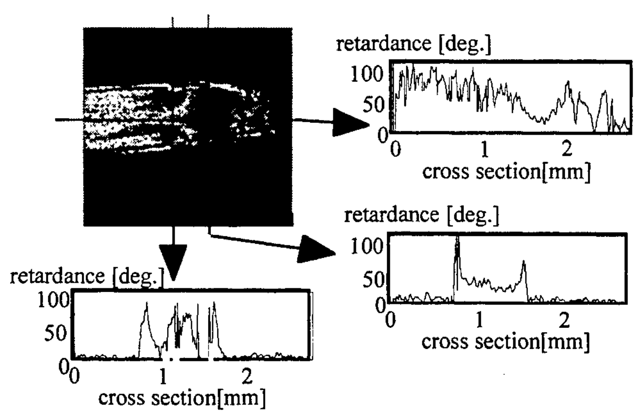


Fig.6 Measurement result of the microscopic distribution of inside disk

birefringence measurement system in Fig.5. This is a transmission type of a microscope. It is possible to detect in a very small area. We tried to make a small sample cut as a sliced piece of the disks to analyze a birefringence distribution of its cross section. Figure 6 shows its result of the cross section of the plastic disk. Its viewing area might be as small as 1x1mm. In the present measurement it is 2.5x2.5mm. We can check an injection process of disks from its birefringence distribution. Although this result seems a little bit noisy, because the light source used is a coherent light (a He-Ne laser), it might be reduce by using a incoherent light source.

4. CONCLUSION

A disk inspection system was proposed using two dimensional birefringence distribution measurement. This system is very powerful that several kinds of disks, such as DVD, MO and/or CD-R, for the next generations require high quality of plastic surface can be applicable. The birefringence measurement is necessary to determine the relative retardation and the azimuthal angle of the fast axis in an optical disk. Several images captured by a CCD camera are enough for one birefringence distribution analysis. We have shown an experimental procedure and the results of some famous optical disks are discussed. This information is useful not only to analyze its flatness, but also to observe its molecular orientation .

5. REFERENCES

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